

Classification of the types of mechanical loading to the head

There are 2 types of mechanical loading:

- A) static loading : loading that's applied to the head slowly, occurring in a period greater than 200 ms e.g. earthquake, slowly moving vehicle that trap head against hard object. It usually result in multiple comminuted fractures of the vault or skull base often with preserved consciousness & usually there's no severe neurological deficit unless there's distortion or deformation of the brain.***
- B) dynamic loading: (most common type), loading that's applied rapidly to the head typically in duration less than 50 ms, it's of 2 types:***

1) impulsive loading :occurs when the head set into motion or when the moving head is arrested without it's being impacted e.g. blow to the thorax or face can often set the head into violent motion with out direct impact to the skull.

Impulsive loading result in inertial forces in the brain with subsequent injuries.

2) impact loading:is the most frequent type of dynamic loading & usually results in combination of contact forces & inertial forces

The contact phenomena are group of mechanical events that occur both near & distant from point of impact.

The impulsive & impact loading finally lead to brain tissue strain (deformation) which is of 3 types : compression, tension & shearing.

Mechanistic types of head injuries

A) contact injuries

1) local contact injuries: injuries that occur locally at or near site of impact e.g. skull fractures (linear or depressed), some basilar skull fractures, extra-dural hematoma, coup contusion.

2) remote contact injuries: injuries that occur away from site of impact

a) local & global skull distortion (skull volume changes) e.g. vault fractures, basilar fractures, countercoup contusion.

b) stress or shock wave originating at the point of impact & radiating in three dimensional in the brain like waves in water e.g. intra-cerebral hematoma , basilar skull fractures, intermediate coup contusion.

B) head motion (inertial) injuries (acceleration-deceleration injuries)

- 1) skull-brain relative motion: e.g. subdural hematoma, countercoup contusion, intermediate coup contusion.***
- 2) brain deformation e.g. concussion, diffuse axonal injury & tear hemorrhage.***

Types of head acceleration

- 1) translational acceleration occurs when center of gravity of the brain (which is approximately in the pineal region) moves in straight line as in vertex impact, it results in skull-brain relative motion with subsequent brain injury such as intra-cerebral hematoma. It doesnot cause diffused brain injury.**
- 2) rotational acceleration:there's rotation about center of gravity of the brain without center of gravity itself moving. It doesnot occur alone & usually only seen in association with angular acceleration.**
- 3) angular acceleration:combined features of both translational & rotational acceleration. It's most common type & most injurious clinically. It can cause all types of head injury except skull frctures & extra-dural hematoma.**

Pathophysiology of traumatic brain injury (TBI)

A) primary pathology: the initial events in head injury involves direct impact injury to the brain e.g. contusion, axonal injury etc....

B) secondary pathology: the primary injury trigger a sequence of secondary alteration in brain metabolism, ion homeostasis, intra-cranial hemodynamics & brain water compartmentation e.g. decrease ATP production with anerobic metabolism, acidosis , free radicals release, increase extra-cellular K & adenosine, increase intra-cellular Ca , glutamate release, alteration in cerebral autoregulation so that moderate or transient hypotension can cause cerebral ischemia.

Systemic manifestations of head injury

Traumatic brain injury (TBI) may cause abnormalities in systemic homeostasis & organ function occurring either immediately or may evolve over hours or days.

A) abnormalities of water & electrolyte homeostasis

They are due to hypothalamic-hypophyseal dysfunction & include

- 1) excessive water retention or loss (most common abnormality)***
- 2) diabetes insipidus with polyuria***
- 3) isolated hypernatremia in the absence of diabetes insipidus***
- 4) syndrome of inappropriate secretion of ADH (SIADH) with hyponatremia & increase blood volume***
- 5) cerebral salt wasting syndrome (CSWS) with hyponatremia & hypovolemia***

due to defect in atrial natriuretic polypeptide.

B) other hormonal abnormalities

Anterior pituitary dysfunction due to injury to the hypothalamic-hypophyseal –portal system with pituitary ischemia

C) metabolic abnormalities : due to increase level of catecholamines, enkephalines & cytokines resulting in hypermetabolism, hyperglycemia, hypercatabolism & decrease cellular immunity.

D) cardio-pulmonary malfunction

e.g. hypotension, bradycardia, decrease cardiac output arrhythmia.

Neurogenic pulmonary edema: is a fulminant condition that may occur within minutes of head injury or may be delayed by 24-48 hours & characterize by alveolar & tracheo-broncheal flooding by a blood-tingged protein rich fluid, CXR reveal white lung due to diffuse infiltration of lung parenchyma

E) coagulopathy & DIC